

FeII and FeI emission in IRAS 07598+6508 and PHL 1092

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Abstract

One of the puzzles in understanding the spectra of active galactic nuclei (AGN) is the origin of the FeII emission. FeI emission, if present, will help reveal the physical conditions of the emitting gas. In an attempt to verify the presence of FeI lines, high S/N spectra of two FeII-strong quasars, IRAS 07598-6508 and PHL 1092, were obtained at the Multiple Mirror Telescope and the Steward 2.3 m Telescope. We have identified emission lines of FeI and TiII. The source of energy for FeII, FeI and TiII emission is probably not from ionization by the photon continuum, but heat. The high rate of energy generation and the presence of both high and low velocity gas indicate that the heat is generated not over a large area, but a narrow band in accretion disk, in which the rotational speed decreases rapidly.

1. Introduction

One of the puzzles in understanding the spectra of active galactic nuclei (AGN) is the origin of the FeII emission. This was emphasized by Wills, Netzer, & Wills (1985) who pointed out that in many AGN the strong FeII emission, in relation to that of $\text{Ly}\alpha$, cannot be accounted for by standard photoionization models (Kwan & Krolik 1981; Kwan 1984; Wills, Netzer, & Wills 1985; Collin-Souffrin, Hameury, & Joly 1988). Adding to the bewilderment is the discovery of several AGN with super strong FeII emission (Bergeron & Kunth 1980; Lawrence et al. 1988; Lipari, Terlevich, & Macchetto 1993). The FeII $\lambda 4570/\text{H}\beta$ ratios in them appear to be several times larger than those found in strong FeII emitters. Bergeron & Kunth (1980) also noted the presence of FeI features in PHL 1092, and Wills, Netzer, & Wills (1985) mentioned that in some objects they found a flux excess above their model fits at wavelengths corresponding to those of strong FeI multiplets, but cautioned that FeII lines might actually be the contributors. FeI emission, if present, will help reveal the physical conditions of the emitting gas, but, as far as we know, there has been no further published record.

In an attempt to understand the FeII emission, and to verify the presence of FeI lines, we have obtained spectra of IRAS 07598+6508 and PHL 1092, using the MMT telescope. In the next section we give details of the observations. We present arguments for the identification of FeI and TiII features in §3, and discuss the origin of the FeII, FeI and TiII emission in §4.

2. Observations

One set of observations of IRAS 07598+6508 was made at the MMT Spectrograph with the T I 1200×800 CCD in the red channel on November 3, 1992. A 600 lines mm^{-1} grating was used. The wavelength coverage was between 3500 and 5250 Å, with a resolution of about 5 Å. The slit width was 3.5". Two exposures, 20 minutes each, were taken. The seeing was poor, so the spectrum was not photometric. Another set of spectra of IRAS 07598+6508 was obtained at Steward Observatory 2.3m telescope with a B & C

spectrograph and a 1200×800 CCD on February 2, 1994. Three exposures of a total of 100 minutes were taken with a slit width of $3''$ and a $400 \text{ lines mm}^{-1}$ grating in the second order, covering a wavelength range of 3600 to 5200 Å. The flux level of this spectrum is accurate to within 15%. The redshift of this object is 0.1483, as derived by Lawrence et al. (1988).

The observations of PHL 1092 were made at the Cassegrain focus of the Steward Observatory 2.3m telescope with a B & C spectrograph and a 1200×800 CCD on September 23, 1992. A $600 \text{ lines mm}^{-1}$ grating was used. The wavelength coverage was between 4050 and 6150 Å. The width of the long slit was $1.5''$, and three exposures, each 40 minutes long, were taken sequentially. PHL 1092 has a redshift of 0.396 (Schmidt 1974).

Standard data reduction was performed using IRAF. The signal to noise ratio of each spectrum is about 50. While the continuum level is difficult to determine, we generate a pseudo-continuum by fitting several points where the observed fluxes are low, and plot the ratio of the observed flux to the pseudo-continuum flux. The pseudo-continuum fit is made with a $n = 2$ polynomial. In this way neighboring features in the spectrum become more distinct because of the smaller vertical scale. The spectra of IRAS 07598+6508 and PHL 1092, when shifted to rest-frame wavelengths, are very similar. We will use the former spectrum to demonstrate our identification of the spectral features.

3. Identification of FeI and TiII Features

Fig.1 shows the normalized spectrum of IRAS 07598+6508 from all our observations. In the space above the spectrum we have marked the positions of FeII lines, together with their multiplet numbers. These lines arise from the six odd-parity terms that lie between 4.76 and 5.91 eV above the ground state. Their placements in Fig.1 are such that multiplets at same height originate from the same upper term. In order of increasing height, the six vertical levels where the FeII multiplets are marked above the spectrum correspond to the upper terms that are designated z^6P , z^6F , z^6D , z^4D , z^4P , and z^4F respectively. For example, multiplets 16, 23, and 29 originate from z^4P .

Collisional excitation of the above six terms, followed by permitted radiative decays to metastable even-parity terms, is a major source of FeII emission. The next aggregate of odd-parity terms lies significantly higher, more than 7.4 eV above the ground state. The marked positions in Fig. 1 are then where FeII emission is expected to occur within the observed wavelength range of 3600-5200 Å. The vertical length of each marked line depends on the product $g_u A$, where g_u is the degeneracy of the upper state and A is the spontaneous emission rate. It is equal to $[0.002 + 0.01 \log(g_u A / 10^4)]$, for $10^4 \leq g_u A \leq 10^7$. Lines with $g_u < 10^4$ are not plotted, and lines with $g_u A > 10^7$ have a maximum vertical length of 0.032. This arrangement provides some distinction between strong and weak lines. The relevant atomic data for FeII, and later on for FeI and TiII are gathered from Fuhr, Martin, & Wiese (1988), and Martin, Fuhr, & Wiese (1988) when available, and from Kurucz (1974, 1981), and Kurucz & Peytremann (1975) otherwise.

Even a casual look at the observed spectrum shows that many emission features can be readily identified as FeII lines. Examples are: the series of peaks at 4800-5000 Å that nicely coincide with the positions of strong lines from multiplets 27 and 28; the broad feature at 3600-3800 Å that is most likely contributed by multiplets 1, 6 and 7.

We identify, however, three spectral regions in Fig.1 whose features cannot be accounted for by FeII lines. The first region is from 4050 to 4700 Å. There several emission peaks are present that have no coincident FeII lines. The several FeII multiplets that are present, except for number 3, also cannot be responsible for the bulk of the emission at their positions. Thus, multiplets 23 and 29 are expected to be weak because their upper term has a faster decay route in multiplet 74 (observed wavelength at 7060-7413 Å). The spontaneous emission rate via multiplet 74 is at least three times larger than that of any line of multiplet 23 or 29. Optical depth effects will not be strong as the lower term of multiplet 74 is not only ~ 3.9 eV above the ground state but also ~ 1.3 eV above the lower terms of multiplets 23 and 29. In the same way multiplet 14 is much weaker than multiplets 27 and 38. It is also positioned incorrectly in that its strongest line occurs close to a dip in the observed spectrum. The single marked line belonging to multiplet 15 is

extremely weak as its upper state can spontaneously decay via a transition of multiplet 49 (observed wavelength at 6011 Å) at a rate that is ~ 20 times faster. Multiplet 3, in spite of small A rates, can become strong when multiplet 1 and the UV multiplets of z^6D become very optically thick. Together with the CaII H and K lines, it may contribute to the two emission features at 4520 and 4560 Å. For the other features between 4050 and 4700 Å, we conclude that they are not result of emission from the six lowest odd-parity terms.

The second spectral region we identify where there are few marked FeII lines is from 3810 to 3960 Å. Multiplet 5 and two lines of multiplet 16 lie in that spectral range. Like multiplets 23 and 29, multiplet 16 does not provide a fast decay route for their upper term. The spontaneous emission rate of its line marked at 3955 Å is only $\sim 1/8$ of the total rate from the same upper state down to all levels above a^2P , the lower term of multiplet 16. Its line marked at 3923 Å is stronger, having an A rate about the same as its corresponding total rate to all levels above a^2P . A similar situation hold for multiplet 5. Its upper term, z^6P , decays to a^6S (multiplet 42 at observed wavelengths of ~ 5800 Å), which lies ~ 1.2 eV above the lower term of multiplet 5, at ~ 300 times faster. Based on these considerations, we conclude that the broad feature between FeII multiplets 1 and 4 has a different origin.

The third spectral region is from 5050 to 5150 Å. Of the four marked lines present, only one, at 5072 Å (from multiplet 27) competes effectively for the de-excitation of its upper state. Each of the other three has a spontaneous emission rate that is more than a factor of 10 smaller than the decay rate to a level above its lower term. Although not as evident as is the case with the first or second spectral region, additional emission is also needed here.

We have, thus far, pointed out spectral features in Fig.1 that are not being emitted by the six lowest odd-parity terms of FeII. Examining the permitted transitions of more highly excited terms, we are also confident they are not responsible for the bulk of the emission in those features. First, collisional excitation of those terms require ~ 2 eV or

more energy above that needed to excite the six lowest odd-parity terms. Then those lines that lie within the three spectral regions all have A values of $\leq 10^6 \text{ s}^{-1}$, and are not the dominant transitions from their respective upper states. It is difficult to see how collisional excitation to the higher odd-parity terms can produce the features in the three spectral regions which, taken together, comprise an amount of emission, within the observed wavelength range of 3600-5200 Å, that is comparable to the total in the identified lines from the six lowest odd-parity terms. Second, there are not enough strong lines, with line strength values $gf \geq 10^{-3}$, from upper states within 9eV from the ground state to account for all the features in the three spectral regions.

FeII line coincidence, due to wavelength proximity to within a few Doppler widths, between a UV line originating from one of the six lowest odd-parity terms and another originating from an upper term may over populate a highly excited state and lead to a stronger emission of UV and optical lines from that state. We have examined whether the emission features in the three spectral regions originate from this fluorescence process by employing the list, tabulated by Netzer and Wills (1983), of line pairs whose wavelength difference corresponds to a velocity shift of $\leq 7.5 \text{ km s}^{-1}$. From that list we identify about 20 line pairs such that the upper state that may be over populated as a result of a line coincidence has a transition lying within the three spectral regions. Comparing the spontaneous emission rate of that transition with those of others from the same upper state, we find that the former rate is generally less than 10^{-3} of the total rate. The fluorescence process will therefore enhance little the emission in the optical transitions which the three spectral regions encompass. Rather, it will enhance primarily the emission in the many strong UV transitions. Radiative trappings of these transitions, whose lower states lie at several eVs above the ground state, will be less severe than those of UV transitions originating from the six lowest odd-parity terms. There are also features in the three spectral regions that cannot be identified with transitions from the special upper states. Thus, while we cannot rule out a small contribution to a few features in the three spectral regions from FeII line coincidence and fluorescence, we are confident this process

does not produce the bulk of those emission features.

We believe emission from ions other than FeII is required. In the space below the spectrum in Fig.1 we have marked the positions of emission produced by FeI and TiII. The TiII lines are marked on the vertical level of 0.99 and their multiplet numbers are prefixed by Ti. The many more FeI lines are marked farther below, identified by only their multiplet numbers.

The FeI multiplets shown originate from the 15 lowest odd-parity terms. Unlike those of FeII, the odd-parity terms of FeI are distributed fairly uniformly in an energy-level diagram, so there is not an obvious grouping of them, as in the case of FeII.

Many of the FeI lines marked represent dominant decay routes of their respective upper states. Their spontaneous emission rates, however, occupy a very wide range, from $\sim 10^3$ to $\sim 10^8 \text{ s}^{-1}$, so the procedure used earlier to signal the $g_u A$ value of a line by the plotted vertical length will not provide a fair representation of dominant transitions that happen to have very low A values. For the FeI lines, then, the following procedure is adopted. The vertical length is equal to $[0.1(g_i/\Sigma_i g_i)(A_{ij}/\Sigma_{ij} A_{ij,k})]$, where g_i is the degeneracy of the upper state, $\Sigma_i g_i$ is the total degeneracy of the upper term, A_{ij} is the spontaneous emission rate of the line, and $\Sigma_{ij} A_{ij,k}$ is the total spontaneous emission rate from the upper state to all lower states j of all lower terms k . We assume that population into a given state i of an upper term is proportional to g_i , so the vertical length represents the probability of spontaneous emission of the line photon upon collisional excitation of the upper term. Only lines with vertical lengths equal to 0.001 or more are plotted.

The large number of FeI terms involved and the limited available space in Fig.1 does not allow us to place the line markings in the orderly fashion that was done in the FeII case. Of the FeI multiplets indicated, only several share the same upper term. They are multiplets 7 and 18 which have z^3F as their upper term, multiplets 23 and 41 which have z^5G as their upper term, and multiplets 24 and 42 which have z^3G as their upper term.

A casual comparison between the FeI line positions and the emission features in the first spectral region mentioned above shows that many of the observed features coincide with

strong FeI lines. A firm identification must await detailed calculations of the line intensities. Unfortunately, reliable collisional cross-sections are needed. They are not available, and our qualitative discussion of the FeI excitation below is accordingly hampered.

The three lowest odd-parity terms of FeI are z^7D , z^7F , and z^7P . They lie from 2.4 to 3.0 eV above the ground state. The dominant decay routes from them are contained in multiplet 1 (which lies outside the observed spectrum), 2, and 3 respectively. Judging from Fig.1, we find that the emissions that can be identified with multiplets 2 and 3 are fairly weak, particularly so in the case of multiplet 3. Thus, despite the proximity of those two terms to the ground state, population into them must be relatively slow if other FeI multiplets are to be identified with more prominent features. A plausible cause is that multiplets 2 and 3, linking their respective upper terms to the ground term a^5D , have very small oscillator strengths ($f \sim 4 \times 10^{-5}$), so collisional excitation of them may be comparatively weak.

The next group of odd-parity terms are z^5D , z^5F , and z^5P , lying from 3.2 to 3.7 eV above the ground state. The dominant decay routes from them are contained in multiplets 4, 5 and 6 respectively, which connect down to the ground term. They have large oscillator strengths ($f \sim 10^{-2}$). When their optical depths exceed about 10, 200, and 20 respectively, multiplets 15, 16, and 60, which have observed wavelengths longward of 5200Å, will compete for the de-excitation of z^5D , z^5F , and z^5P respectively. Until the FeI column density becomes very high then, we expect that population into these three excited terms will produce emission largely in multiplets 4, 5 and 6.

Most of the multiplets that contribute to the prominent features in the first spectral region originate from the group of odd-parity terms comprising y^5D , y^5F , z^5G , z^3G and y^3F . These five excited terms lie from 4.1 to 4.65 eV above the ground state. They, together with y^3D (lying at ~ 4.8 eV), have the distinction that their outer-shell electronic configuration, $3d^7 (a^4F) 4p$, has the same inner structure as that, $3d^7 (a^4F) 4s$, of the two lowest excited terms a^5F and a^3F . Thus, radiative transition coefficients between those odd-parity terms and one or both of the two lower even-parity ones are particularly large.

Multiplets 20 ($y^5D - a^5F$), 21 ($y^5F - a^5F$), 23 ($z^5G - a^5F$), 41 ($z^5G - a^3F$), 24 ($z^3G - a^5F$), 42 ($z^3G - a^3F$), and 43 ($y^3F - a^3F$) all have transitions with very strong oscillator strengths ($f \sim 0.1$). We judge that the majority of the population into those five excited terms will produce emission in the above-mentioned multiplets. To generate the prominent features in the first spectral region then, a strong excitation of those five terms, despite their relatively high excitation energies, is required.

FeI Multiplets 2 and 41 can contribute to the emission features in the third spectral region mentioned above, but the broad feature in the second spectral region remains to be identified. Two ions, Cr II and TiII, have strong emission lines there. If the elemental abundance is solar-like, Cr is 5.2 times as abundant as Ti. But collisional excitation of the appropriate Cr II terms, which lie at ~ 6.14 eV above the ground state, requires ~ 2.36 eV more energy than that needed to produce the Ti II lines. This latter consideration, and our judgment that the TiII lines are better positioned to match the broad feature lead us to decide on TiII.

The TiII lines that are marked in Fig.1 originate from the two lowest odd-parity terms. Multiplets 1, 6, and 11 have z^4G as their upper term which lies at ~ 3.68 eV from the ground state, while multiplets 2, 7 and 12 have z^4F as their upper term which lies ~ 0.16 eV farther above. We expect them to be less optically thick than the FeII multiplets, so only the stronger lines, with values of $g_u A \geq 3 \times 10^6 \text{ s}^{-1}$, have been plotted. The vertical length of a marked TiII line is equal to $[0.002 + 0.01 \log(g_u A / 3 \times 10^6)]$, with a maximum of 0.032.

Whereas FeII is a likely cooling agent of the gas, both FeI and TiII are not. The former is readily ionized to FeII, while the latter has an abundance, assuming solar-like, that is no more than 1/300 that of Fe. A condition that favors collisional excitation of the FeI and TiII lines is the comparatively low energy needed. Thus it takes ~ 1.9 eV less energy to produce TiII multiplet 1 than to produce FeII multiplet 27. This translates, at a temperature of 7000 K, to a factor of ~ 23 in the excitation rate. When the gas temperature is low, and the ionization condition is such that a small fraction (≥ 0.01) of

Fe is FeI, cooling due to collisional excitation of TiII and FeI will become important.

Fig.2 shows the observed spectrum of IRAS 07598+6508 obtained on February 2, 1994, and the observed spectrum of PHL 1092. The two spectra are shift to rest-frame wavelengths so that they can be compared directly. We have not labelled the emission features, but it is clear that the two spectra appear very similar. The first and second spectral regions, at rest-frame wavelengths of 3520-4100 Å, and 3320-4350 Å respectively, can be readily identified.

4. Discussion

The above identification of FeI and TiII features, if correct, indicates a small but significant amount of FeI. A quantitative determination of the [FeI]/[FeII] abundance ratio is difficult at present because the underlying continuum is not firmly established, so the observed line intensities are uncertain, and reliable FeII and FeI collisional cross-sections are not available. We guess it is probably greater than 0.01. We can make a somewhat better estimate of the column density, as follows. The line $\lambda 4233.17$ (observed at 4860.95 Å) of FeII multiplet 27 ($b^4P - z^4D$) is strong. Another line from the same upper state, $\lambda 4731.44$ (observed at 5433.11 Å), belonging to multiplet 43 ($a^6S - z^4D$) and having a spontaneous emission rate that is 30 times smaller, is much weaker as we judge from the spectrum of IRAS 07598+5608 obtained by Lawrence et al. (1988). The $\lambda 4233.17$ opacity is then less than or about 30. Assuming an absence of a velocity gradient within the emission column, the Fe II column density is $N_{FeII} \leq 2 \times 10^{19} (7000 \text{ K/T})^{3.6} (\Delta v / 20 \text{ km s}^{-1}) \text{ cm}^{-2}$, where Δv is the intrinsic linewidth (due to thermal or turbulence broadening) and the gas temperature T is assumed to lie between 6000 and 8000K.

We can also make a lower estimate of the luminosity of the FeII, FeI and TiII emission. Assuming that the underlying continuum is smooth, we use the low points (at observed wavelengths of 3615, 4245, and 4690 Å) of the spectrum obtained on February 2, 1994 to demarcate an upper bound to the underlying continuum. It can be roughly gauged from Fig. 2 that over the observed wavelength range of 3600-5200 Å the emission features

altogether constitute a luminosity that is about 1/7 or more of the continuum luminosity. assuming an H_0 of $50 \text{ km s}^{-1} \text{ Mpc}^{-1}$, an Ω of 1, we calculate this luminosity of the emission features to be $4.2 \times 10^{10} L_{\odot}$. It can also be seen from the spectrum of Lawrence et al. (1988) that over the observed wavelength range of 5000-9000 Å the emission features there, excluding H_{α} , H_{β} , and He I $\lambda 5876$, and which consist primarily of FeI and FeI multiplets, are comparably strong in relation to the underlying continuum. FeII UV multiplets, at rest wavelengths from 2200 to 3000 Å, are expected to be even stronger than FeII optical multiplets. Thus, over the observed wavelength range of 2500-9000 Å the luminosity in the FeII, FeI and TiII features is a significant fraction of the total.

Another item of information indicated by the observed spectrum is the narrowness of the lines. This has been noted by Bergeron & Kunth (1980) from their spectrum of PHL 1092. Consider the FeII $\lambda 4233.17$ line, for example. While the linewidth at zero intensity is not easily determined because of line blending and the uncertain continuum level, the narrowness at the peak clearly stands out. When the close proximity of neighboring lines is taken into account, other emission features, such as the ones at observed wavelengths of 4315 and 4795 Å, also point to sharply-peaked individual lines. The observed width of a line is generally ascribed to Doppler broadening, so the narrow line peak indicates that some of the emitting gas have bulk velocities less than 500 km s^{-1} .

We do not think the source of energy for the very strong FeII, FeI, and TiII emission is ionization by the photon continuum. The FeII column density estimated above indicates, for solar-like abundances, a nucleon column density that is sufficient to absorb only the UV ($\geq 13.6 \text{ eV}$) and soft x-ray continuum. Photoionization calculations at that column density and with the typical continuum energy distribution will not be able to produce the strong FeII and FeI luminosity estimated earlier in relation to the underlying continuum. They will also not be able to produce the relative intensity between FeII and hydrogen emission. Lawrence et al. (1988) estimate FeII $4570/H_{\beta}$ to be in the range of 4-8, about an order of magnitude higher than the typical value in AGNs with strong FeII emission. It can also be seen from Fig. 1 that H_{γ} , and H_{δ} , at observed wavelength of 4984 and

4710 Å respectively, are almost invisible amid the FeII and FeI features. It is probably impossible to produce a luminosity in FeII and FeI lines that is at least several times the luminosity in the hydrogen Balmer lines via absorption of the photo continuum beyond 13.6 eV, since photoionization of hydrogen necessarily converts a large fraction of the continuum energy into hydrogen quanta. Enhancement of the FeII and FeI emission by choosing the nucleon density such that continuum from 7.78 to 11.26 eV were also absorbed within the same column density as result of photoionization of FeI would not work, as the FeI luminosity would then be stronger than the FeII luminosity, which is not the case.

We believe the source of energy for the FeII and FeI luminosity is most likely heat. If heat is generated at a rate such that the equilibrium temperature is less than 8000 K, collisional excitation of FeII and FeI multiplets will be more effective coolants than collisional excitation of the Balmer lines of hydrogen, largely because higher excitation energies are needed in the latter process. The very high FeII and FeI luminosity estimated earlier suggests to us that the source of heat is probably not derived from stars, since heating generated from the interaction of HII regions and supernova explosions with the interstellar medium does not generally liberate a large fraction of its energy at temperatures of less than 8000 K.

We think it is simpler and more efficient to produce the heating from an accretion disk around a massive black hole. The high rate of energy generation and the presence of both high and low velocity gas indicate to us that the heat is generated not over a large area such as the Keplerian dependence of the rotational speed on radius produces the velocity dispersion. This is because the high and low velocity gases would then lie at very different distances from the black hole, and it would be difficult to generate a heating rate such that FeII emission is the dominant coolant over the wide range of distance. We speculate that the heat may be generated in a narrow band in which the rotational speed decreases rapidly, in a way described below.

Recently, Hirotani et al. (1992) have studied the interaction between accreting matter

and magnetic field in the magnetosphere of a Kerr black hole. In their model the matter originates from a geometrically thin disk, and the accretion onto the black hole occurs along the magnetic field lines which arise from the disk and thread the event horizon. The angular velocity Ω_F of such a field line will depend on Ω_H , the angular velocity of the black hole, and $\Omega_K(r)$, the angular velocity of the rotating disk. Studies of time-stationary, axisymmetric flow in the magnetosphere of a Kerr black hole find that $\Omega_f \leq \Omega_H$ (Phinney 1983; Punsly & Coroniti 1990). At the places where matter climb onto the field lines, which depend on the magnetic field strength, it is likely that $\Omega_k > \Omega_F$, and heat will be generated as the matter loses part of its angular momentum before falling along the field lines. This situation is analogous to what Ghosh & Lamb (1979) envision in their model of accretion onto a neutron star from the surrounding disk.

We think that the FeII emission is produced in the region mentioned above where orbital energy is dissipated. In the case of IRAS 07598+6508 we estimate that the rotational speed decreases from $\sim 5 \times 10^3 \text{ km s}^{-1}$ to $5 \times 10^2 \text{ km s}^{-1}$. Taking account of the large velocity gradient within the dissipation region, the FeII column density in the direction perpendicular to the disk is then $N_{FeII} \leq 2 \times 10^{21} (7000 \text{ K/T})^{3.6} \text{ cm}^{-2}$. If the energy dissipation occurs at $T < 800 \text{ K}$, FeII emission is most probably the major coolant. At higher temperatures hydrogen line and continuum emission will begin to dominate. The weak hydrogen emission, in relation to FeII emission, that is observed and the conspicuous presence of FeI and TiII features, which require lower excitation energies than the FeII features, are then mutually consistent.

Once the gases radiate away their excess orbital energy, they will corotate with the field lines and fall towards the black hole. The bulk of their gravitational potential energy is likely to be released in the magnetic funnel close to the event horizon, thereby generating the major portion of the continuum energy. Away from this continuum source, the diffuse accreting gas will probably be heated to the Compton temperature (Krolik, McKee & Tarter 1981; Mathews & Ferland 1987). If dense, much cooler condensations can be formed within the flow, they will be logical candidates for the broad emission-line

clouds. With their infalling velocity increasing rapidly from 0 to $> 10^4$ km s $^{-1}$, the line intensities and profiles they produce may match the observed results more easily than kinematic models in which the high and low velocity emission occur at very different distances.

While our speculation of the origin of the FeII emission is stimulated by its unusual strength in IRAS 07598+6508 and PHL 1092, we suspect the same origin is true for those AGN whose strong FeII emission cannot be accounted for by photoionization models. It would be useful to examine the FeII emission of these objects at high signal to noise and with careful modeling to see if the physical conditions and kinematic structures required point to a similar scenario.

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Figure captions

Fig.1 Normalized spectrum, from 3500 to 5250 Å of IRAS 07598+6508. The vertical scale gives the ratio of the observed flux (see text in §2). In the space above the spectrum we have marked the locations of all FeII lines, excepting two, that originate from the six lowest odd-parity terms of FeII, fall within the observed wavelength range of 3600-5200 Å, and have values of $g_u A \geq 10^4 \text{ s}^{-1}$. The multiplet number (Moore 1945) are also listed. A line, at an observed wavelength of 4014 Å ($g_u A = 3.59 \times 10^4 \text{ s}^{-1}$), belonging to the transition from z^4D to a^2G , has not been plotted because it does not have a multiplet number. Another line at 4752 Å ($g_u A = 1.07 \times 10^4 \text{ s}^{-1}$), belonging to the transition from z^4P to b^4F (multiplet 39), has also not been plotted because of insufficient room in that part of figure. We have also marked the Ca II H and K doublet and, in the space below the spectrum, multiplets originating from the two lowest odd-parity terms of TiII, and multiplets originating from the 15 lowest odd-parity terms of FeI.

Fig.2 Comparison of the observed spectra of IRAS 07598+6508 and PHL 1092.